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(54) **APPARATUS AND METHOD FOR REGULATING AND MONITORING A CHARGEABLE DEVICE WITH MINIMAL OPERATOR INTERVENTION**

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H02J 7/04 (2006.01)

(52) **U.S. Cl.** **320/162**

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See application file for complete search history.

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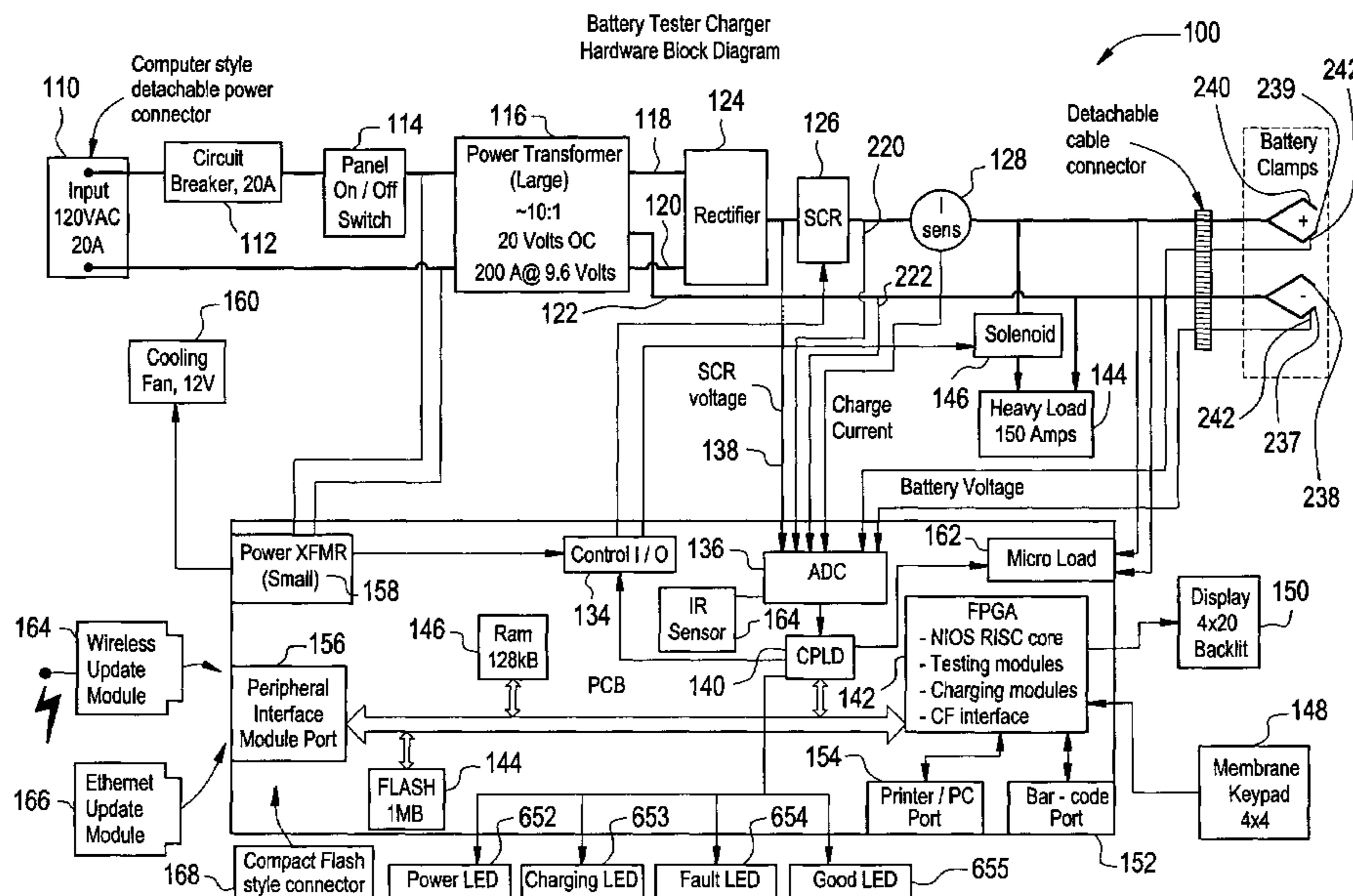
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(57) **ABSTRACT**

A method and apparatus that enables the load applied to a battery to be regulated. Regulation of the load to the battery is based upon a load request from which a set-point is derived in a microprocessor. From this set-point, voltage is either allowed to pass or not to pass through a regulator.

21 Claims, 6 Drawing Sheets



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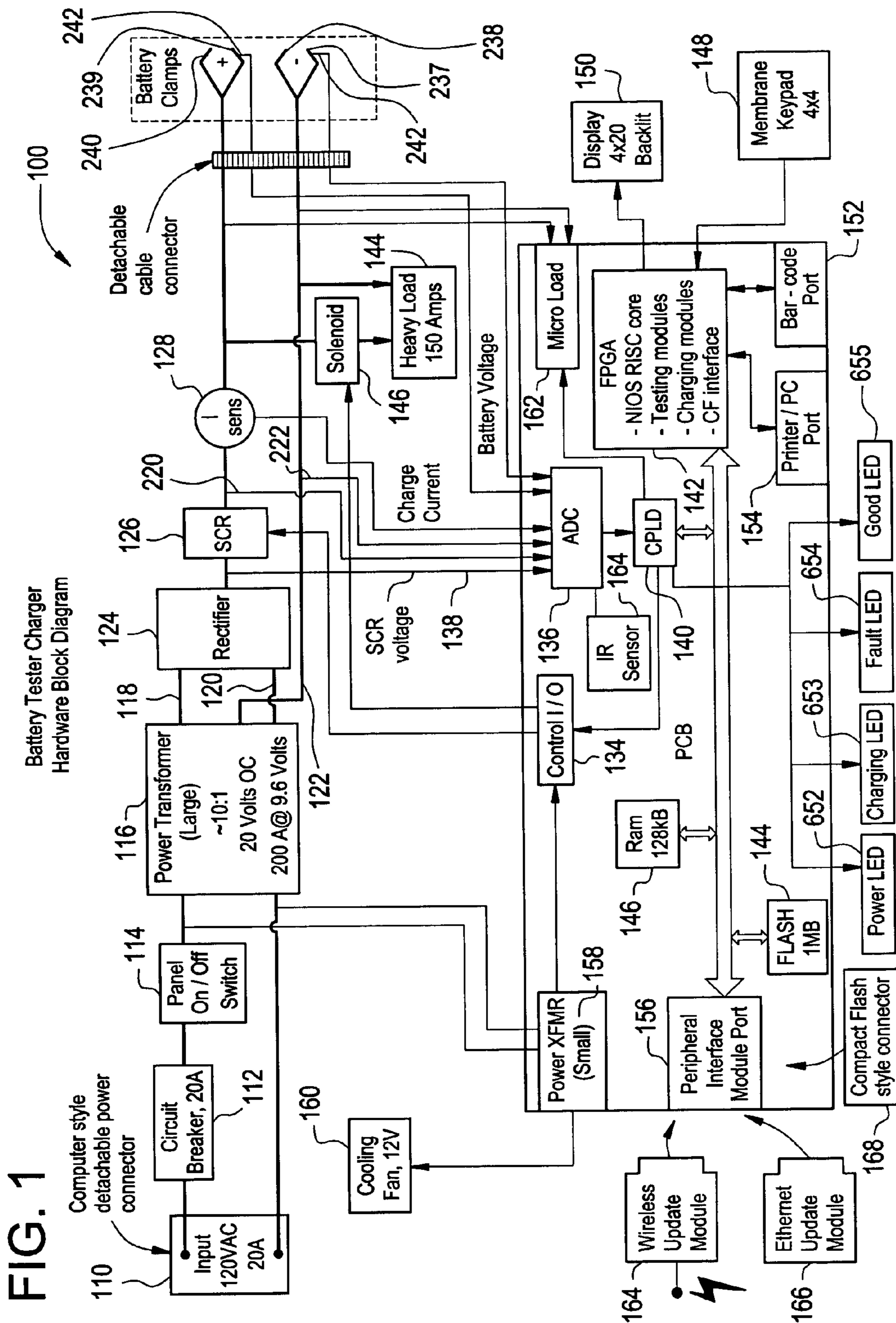


FIG. 2

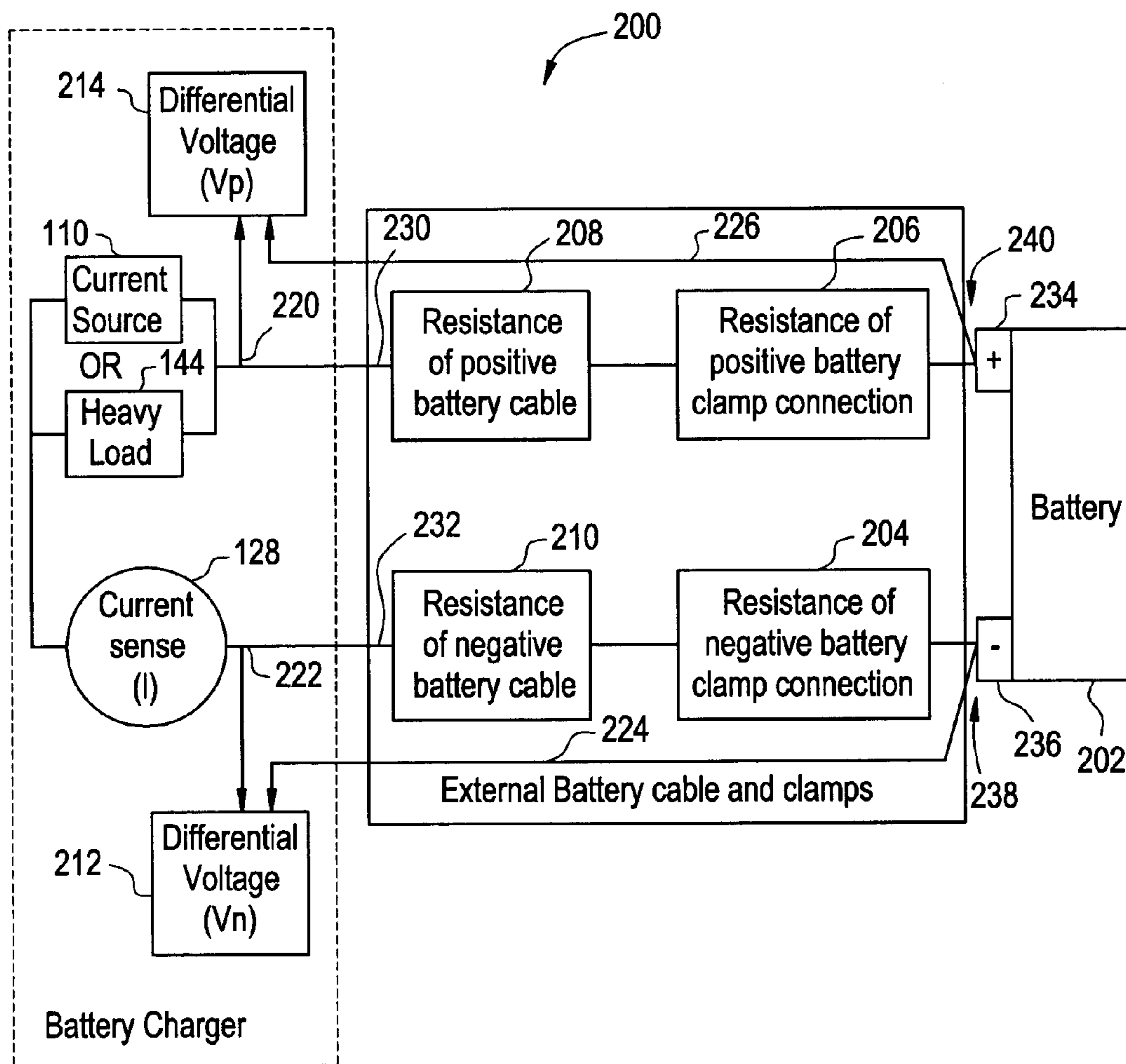


FIG. 3

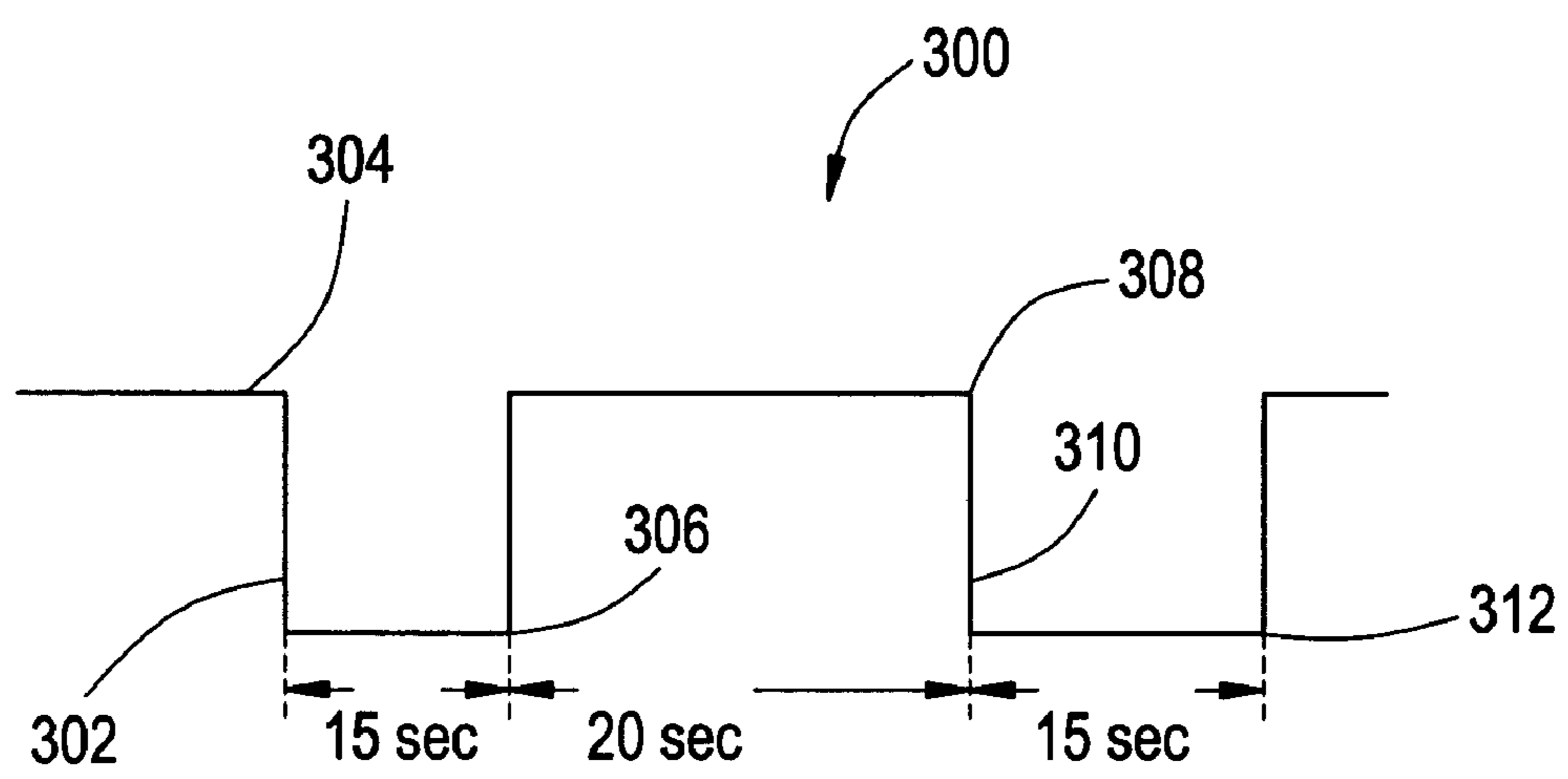


FIG. 4

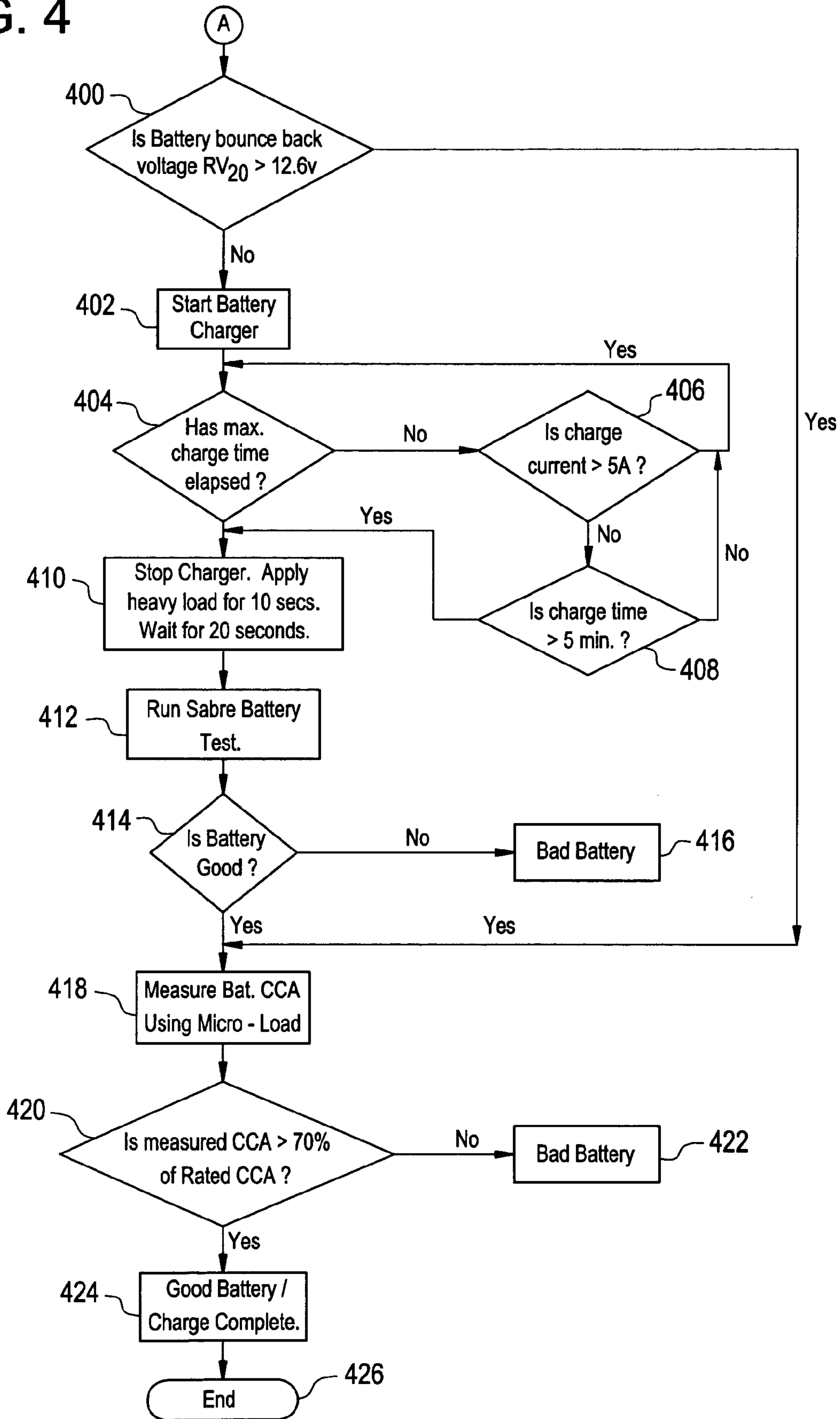


FIG. 5

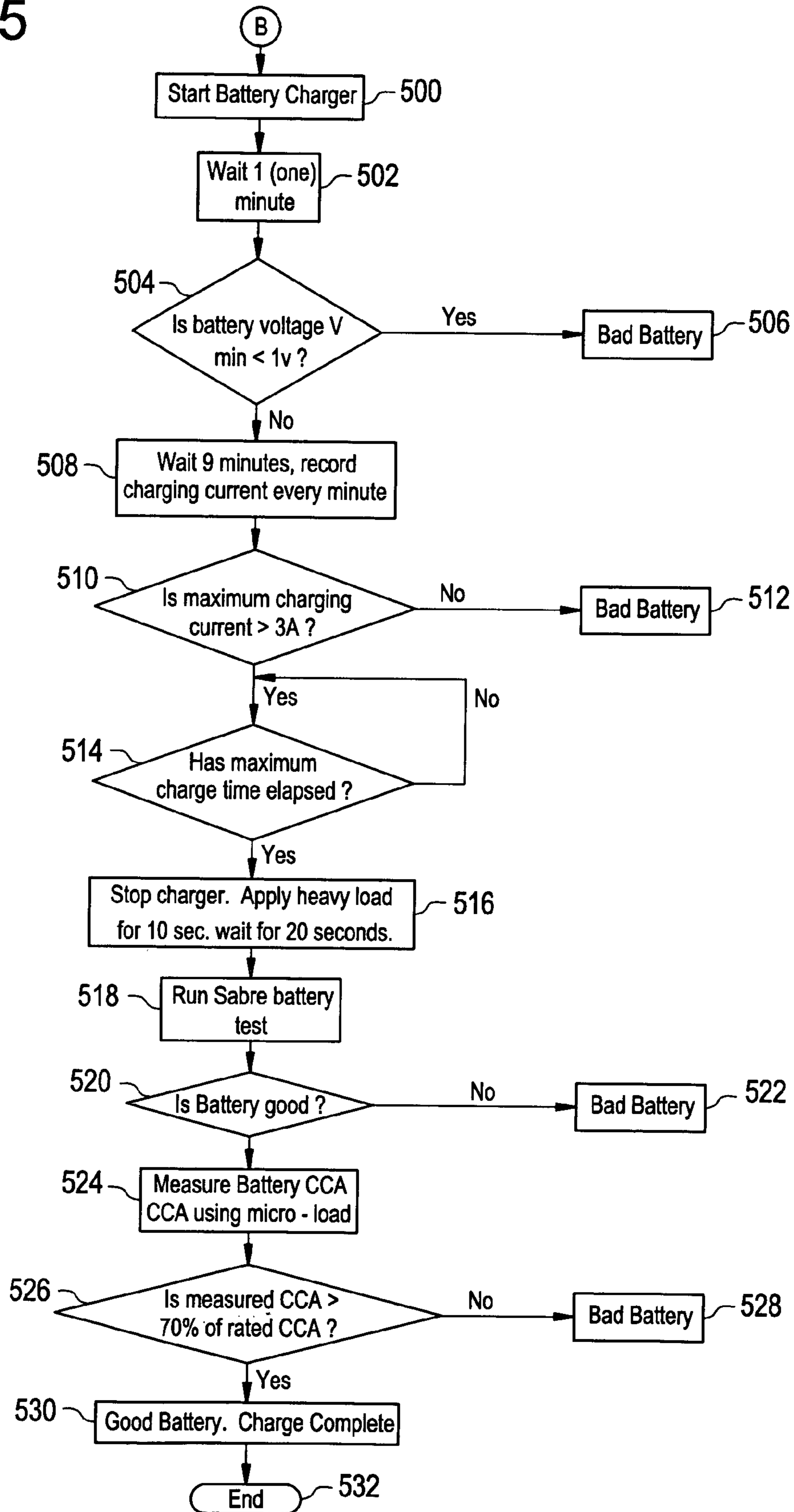
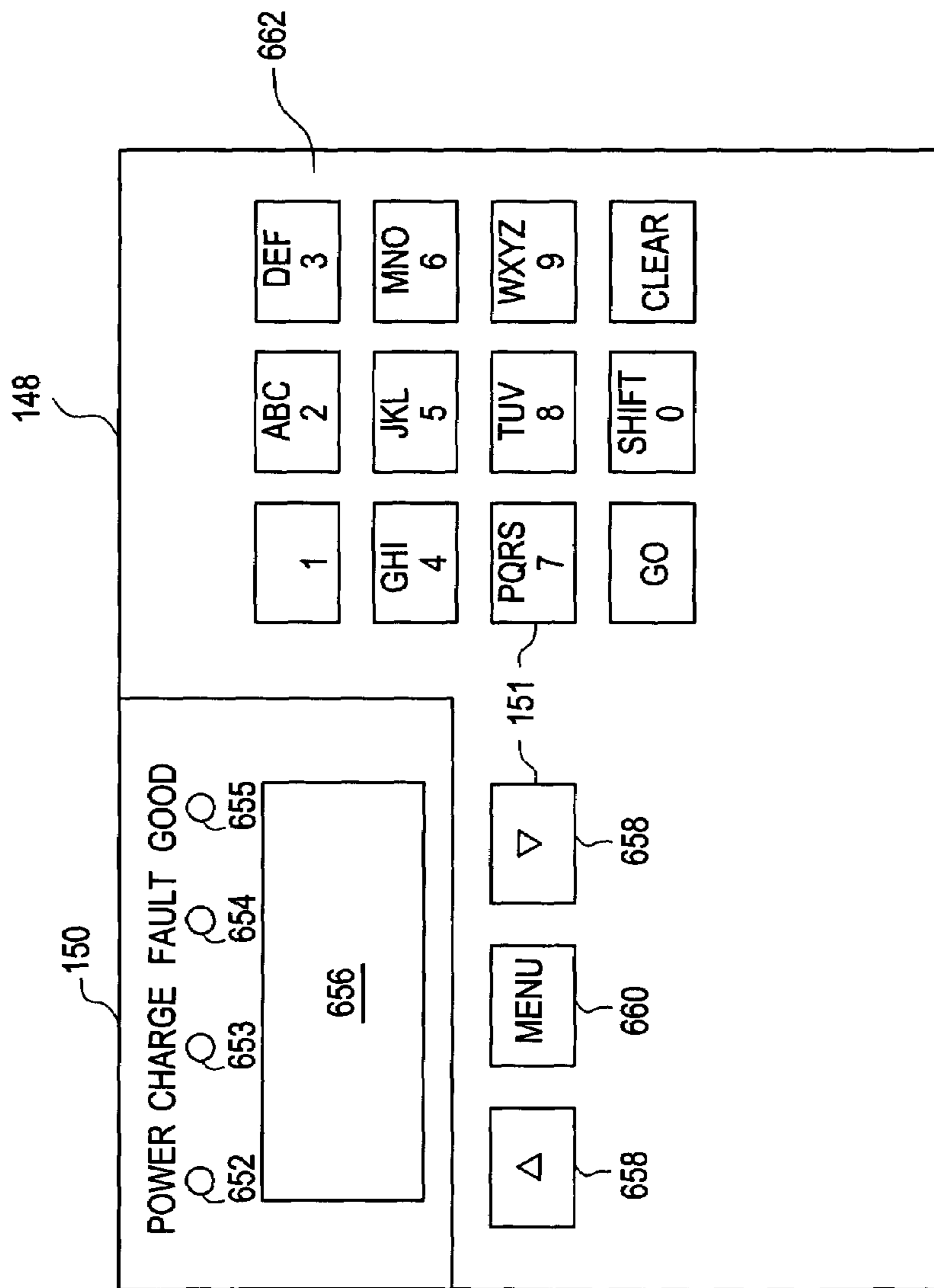


FIG. 6



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**APPARATUS AND METHOD FOR
REGULATING AND MONITORING A
CHARGEABLE DEVICE WITH MINIMAL
OPERATOR INTERVENTION**

Under the provisions of Section 119(e) of 35 U.S.C., Applicants hereby claim the benefit of the filing date of Prior Provisional Application No. 60/391,619, filed Jun. 27, 2002, for the above identified United States Patent Application.

FIELD OF THE INVENTION

Embodiments of the present invention generally relate to a power source charger and tester. More particularly, the present invention relates to an apparatus and method for regulating the load, current and/or voltage that is applied to battery.

BACKGROUND OF THE INVENTION

Rechargeable batteries are an important source of clean portable power in a wide variety of electrical applications, including automobiles, boats and electric vehicles. Lead-acid batteries are one form of rechargeable battery that are commonly used to start engines, propel electric vehicles, and to act as a source of back-up power when an external supply of electricity is interrupted. While not particularly energy efficient, due to the weight of lead in comparison to other metals, the technology of lead-acid batteries is mature. As a result, the batteries are cheap, reliable, and readily produced and thus, continue to constitute a substantial portion of the rechargeable batteries being produced today.

The ability of lead-acid batteries to deliver large amounts of electrical power is well known, particularly when associated with the starting and powering of motor vehicles. Because the lead-acid batteries can be depleted of power overtime, such as when they are not in use over a period of time, or when a light in a car is left on for an extended period of time, they need to be recharged and tested. A number of battery testers and chargers have thus been developed to charge and test the lead-acid battery.

Most conventional battery charger/tester are equipped to provide multiple charging rates for charging different size batteries. The multiple charging rates are achieved by varying the charging voltage at the battery terminals, generally by changing the transformer primary/secondary winding ratio. An operator manually selects the rate at which the battery should be charged and also the duration of the charge cycle if the charger is equipped with a timer function.

Many defects found in lead-acid batteries and other types of batteries are the result of poor recharging control in conventional chargers. For example, an operator may undercharge or overcharge the battery at a very high rate resulting in the deterioration of the battery. Overcharging a battery wastes energy, reduces the life of the battery, and may permanently damage the battery. Additionally, conventional battery chargers can also include testers with the appropriate gauges in order to determine the current state of charge in a battery, how long and at what rate a particular battery should be charged, whether it is safe to charge the battery, and whether the battery is capable of accepting a charge.

Once the battery charger/tester is in operation, the operator must return to check the status of the battery to ensure that the battery is charging properly. Because conventional battery requires actual visual inspection of the gauges, the operator can waste valuable time and money to inspect all

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the batteries that are currently being charged instead of generating money by working on other projects.

During the charging period of the battery, temperature of the battery is an indicator as to how successfully the battery is accepting the charge. Different batteries accept the charge in a number of different ways. For example, some batteries heat up beyond a normal range. Anything beyond this normal range is an indication that the battery is not accepting the charge in an efficient manner. There is a need for a battery's charger/tester to include a temperature sensing device, which monitors the device throughout the entire processing charging and testing process. There is a further need to provide the collected temperature data back to the charger to enable it to adjust the charge/test rate of the battery based upon this data.

Standard battery chargers require a user to connect the battery and then turn on the charger for a set-period of time to charge the battery. With this method, there are a number of battery conditions that render this method unsafe and ineffective. For example, if the battery is damaged internally or contains a short, the battery is not able to maintain a charge. The charge time then amounts to an inefficient use of the charger. Furthermore, applying a load to such a battery or applying an incorrect load to a chargeable battery can result in a dangerous situation, such as the battery exploding.

With these standard battery chargers, there is a need to have a system test and monitor the battery automatically without the need for the operator to hover over the machine. There is a need for the battery charger to initially test the battery in addition to charging the battery. There is a further need for the charger to compile all the data from the battery and analyze it to determine the best possible action to take in regards to charging the battery.

Standard battery chargers additional do not allow the operator to select various voltages and amperages to charge the battery. These chargers allow the operator to select among a limited choice of cycles, which do not include amperage or current. There is a need for a charger to allow the operator to choose a specific current and voltage at which he wants to charge the battery. As a result of this selection by the operator, the charger would then allow that voltage to pass onto the battery. Furthermore, there is a need for the charger to aid an inexperienced individual with the selection of the correct voltage and current to apply to the battery.

SUMMARY OF THE INVENTION

It is therefore a feature and advantage of the present invention to provide a method and apparatus for regulating the load applied to a battery.

In another aspect of the present invention, a method and apparatus is provided for determining a set-point in a microprocessor and then using the set-point to regulate power to the battery. The above and other features and advantages are achieved through the novel use of a regulator and a microprocessor as herein disclosed. The apparatus includes a battery charger and a regulator linked to the battery charger that permits a selected load to pass to a battery. It can further include a battery charger and a microprocessor. The regulator can be a thyristor or a silicon control rectifier. The microprocessor calculates what load to pass through the regulator based upon the set-point. The set-point is then used to regulate what load is permitted to pass to the battery.

In another aspect of the invention, a method is provided for regulating the load to a battery. The method includes the steps of receiving a request for a load to apply when

charging a battery, determining a set-point from the request and regulating the load to the battery. Further steps can include preventing power from reaching the battery that falls outside the set-point and receiving power from a rectifier to apply to the battery. The power can be in the form of a rectified wave form on which the set-point is placed. All power from the set-point forward is allowed to pass to the battery.

In yet another aspect of the invention, an apparatus for regulating the load to the battery includes means for receiving a request for a load to apply when charging a battery, means for determining a set-point from the request and means for regulating the load to the battery based upon the set-point. The apparatus can further include means for preventing power from reaching the battery that falls outside the set-point and means for receiving power from a rectifier to apply to the battery.

There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof that follows may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described below and which will form the subject matter of the claims appended hereto.

In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein, as well as the abstract, are for the purpose of description and should not be regarded as limiting.

As such, those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a hardware block diagram of an embodiment of the current invention.

FIG. 2 is a hardware block diagram.

FIG. 3 is a diagram of the process for applying a load to an open circuit in accordance with a preferred embodiment of the present invention.

FIG. 4 is a flowchart of the process for testing and charging partially charged batteries in accordance with a preferred embodiment of the present invention.

FIG. 5 is a flowchart of the process for testing and charging discharged batteries in accordance with a preferred embodiment of the present invention.

FIG. 6 is a front view of a display and keyboard of one embodiment of the current invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention relates a battery charger/tester that includes a regulator for allowing differing voltages and currents to be applied to a battery.

FIG. 1 is an embodiment of the current invention. The battery charger/tester 100 ("charger 100") can include a power source 110 that provides a 120V (volts) AC (alternating current) to the charger 100. A circuit breaker 112 is provided to prevent damage that can be caused by a sudden power surge or a short in the system. A power switch 114 is linked to the power source 110 to enable the operator to turn the charger 100 on or off.

A power transformer 116 is provided to step down both the voltage and current to a level that enables the charger 100 to charge and/or test a battery. In a preferred embodiment, the power source 110 supplies the charger 100 with 120V AC. The power transformer 116 reduces the 120V AC to approximately 20–25V AC, which is optimal for charging the battery. Two lines 118, 120 from the power transformer 116 are inputted into a rectifier 124 and a third line 122 is directly coupled to the negative clamp 238. The lines 118, 120 pulse alternately through a full-wave rectifier 124 at a cycle of 60 Hz. The diodes of the rectifier 124 convert the positive AC voltage to DC (direct current) power supply. The third line 122 provides a return path for the negative voltage of outputs 118, 120 to return to the transformer 116.

A silicon control rectifier (SCR) 126 or thyristor, which is a regulator is included in the preferred embodiment to regulate the output from the rectifier 124 to the battery. Exiting from the rectifier 124 is a pulsed positive sine waveform with peak voltages and current. The sine waveform results in varying voltages and current being outputted from the rectifier 124. The SCR 126 essentially operates as a switch allowing certain voltages and/or current to pass to the battery.

The operator can choose either a voltage or a current or both to charge the battery. This selection is called a set-point. This set-point is then transmitted to a FPGA 142 (field programmable gate array, discussed below), which then determines at which point in the sine wave to allow voltage to pass through to the battery. This point in the sine wave is related to the set-point as chosen by the operator. The set-point, depending on the selection of the operator, is situated on the sine wave by starting from the end of the sine wave and working in a rearward direction. Once the set-point is located on the sine wave, the voltage underneath the sine wave is allowed to pass through. Therefore, the set-point voltage is a mean value of a range of voltages.

For example, if the operator decides to charge the battery at 12V, this set-point of 12V is entered into the charger 100. The set-point is transmitted to the FPGA 142, which then determines at which point in the sine wave to allow the voltage or current to pass through to the battery. The 12V set-point in this example permits voltages larger than and less than 12V to pass through to the battery. The mean of the voltages distributed to the battery will approximately equal twelve volts.

The SCR 126 operates essentially as a switch and allows current or voltage to pass to the battery at a set-point fixed by the operator. The SCR 126 can operate based on either voltage or current or a combination thereof. The SCR 126 is normally switched off until it receives a signal from an I/O control (input/output) 134. The voltage or current exiting from the rectifier 124 is transmitted to an ADC (analog-to-digital converter) 136. The ADC 136 in turn transmits the voltage or current information to a linked CPLD (computer programmable logic device) 140, which is linked to the FPGA 142. The FPGA 142, simulating as a processor, determines the operability of the SCR 126 by comparing the previously programmed set-point value with the output value of the rectifier 124. If the output value of the rectifier

124 is equal or greater than the set-point of the SCR 126, then the FPGA 142 instructs the I/O control 134 to send a signal to the SCR 126 to allow the output voltage or current to pass to the battery. For example, if the operator desires a minimum current of 20 amps, the SCR 126 will allow a current equal to or exceeding 20 amps to pass to the battery.

A current sensor 128 is provided at the output of the SCR 126 to monitor or sense the current exiting from the rectifier 124 and the SCR 126. The current from the rectifier 124 is relayed to the ADC 136, which like the voltage is fed to the CPLD 140 and then onto the FPGA 142. The FPGA 142 verifies if the current from the rectifier 124 is equal to or exceeds the current set-point value. The output from the current sensor 128 is connected to the battery clamps 238, 240.

FIG. 2 illustrates a battery tester charger 200 according to one embodiment of the invention. A battery 202 having a positive terminal 234 and a negative terminal 236 may be attached to the battery tester charger 200 via a positive clamp 240 and a negative clamp 238 located at an end of the respective positive and negative cables 230, 232.

In a preferred embodiment, the battery tester charger 200 can determine whether the connections between the battery 202 and the clamps 238, 240 are acceptable. A connection test may be performed at either the positive 240 or the negative clamp 238 connection by applying the connection test to the positive components 230, 240 or negative components 232, 238 of the battery tester charger 200. Of course, applying the connection test to both components will test both the positive and negative connections. The connection test may be performed by comparing the voltage in the battery cables 230, 232 upstream from the connection of the clamps 238, 240, and the voltage at the connection of the clamps 238, 240. Voltage loss due to cable resistances 208, 210 may be considered and subtracted from the difference in voltage at the clamps 238, 240 and the upstream position. Additional differences in voltage between the upstream position and the connections of the clamps 238, 240 may be caused by clamp connection resistances 206, 204.

The testing of the battery connections can be applied to either the positive or negative components to test the connections individually or can be applied to both components to test both connections. The external battery cables 230, 232 are attached to the respective terminals 234, 236 of the battery 202 via the respective clamps 240, 238. Standard clamps, such as alligator clamps, may be used.

A portion 237, 239 (FIG. 1) of each clamp 238, 240 is isolated from the remainder of the clamps 238, 240 and the associated cables 232, 230. Portions 237, 239 can be isolated from the remainder of the clamps 238, 240 by a non-conductive element. The cables 232, 230 can carry a large current, either to the battery 202 when charging or from the battery when the battery is in use. The isolated portions 237, 239 may be connected to another device to determine the voltage at terminals 234, 236. For example, the isolated portions 237, 239 may be attached to high impedance wires 226, 224 to differential operational amplifiers 214, 212 (opp. amp) as shown in FIG. 2. Alternately, in some optional embodiments, as shown in FIG. 1, the high impedance wires 226, 224 may be attached to the ADC 136.

The battery connections may be tested to determine the resistances 206, 204 associated with the connection when the battery 202 is charged by a current source 110 or exposed to a heavy load 144. Whether the battery 202 is charging or in use, large current will flow through the cables 230, 232 and clamps 240, 238. A sensor 220, 222 in the battery charger tester 200 senses the voltage upstream from the

clamps 240, 238 and the battery terminals 234, 236 connections and inputs a signal representative of the voltage to opp amps 214, 212 or optionally to the ADC 136. For example, in some optional embodiments of the invention, the voltage may be sensed upstream from the current sense 128 in both cables 230, 232 as shown in FIG. 1. As mentioned above, voltage is sensed in the isolated portions 237, 239 and compared to the voltage sensed upstream. The cable resistances 208, 210 are known, and the portion of the voltage difference between the voltage in the isolated portions 237, 239 and the voltage at the upstream position is accounted for by the cable resistances 208, 210. The remaining voltage difference between the voltage measured at the isolated portions 237, 239 and the upstream positions is due to the resistances in the clamps 240, 238 and terminal 234, 236 connections. In optional embodiments of the invention, cable resistances 208, 210 and the associated difference in voltage due to cable resistances 208, 210, may be neglected or approximated.

The resistance of the connections 206, 204 can be analyzed using Ohm's law, $V=IR$, where V stands for voltage, I stands for current, and R stands for resistance. Simple algebraic manipulation yields $R=V/I$. The unknown connection resistances 206, 204 associated with the connection can be expressed in terms of known parameters of current and voltage, thus the resistances 206, 204 can be determined.

Once the connection resistances 206, 204 are determined, each connection can be evaluated to determine whether the connection is acceptable or not. In one embodiment, a method is provided and compares the connection resistances 206, 204 against a pre-determined acceptable and non-acceptable range of connection resistance. Based on the comparison, the operator can determine whether the connection is acceptable or not.

In an alternative embodiment, a method is provided to compare the voltage differences between the isolated portions 237, 239 and the voltage in the cables 230, 232 at the upstream positions. If the difference in voltage between the two locations is negligible, then the connection is likely to be acceptable. Optionally, the difference in voltage due to cable resistances 208, 210 may be subtracted from the voltage difference or otherwise accounted for in determining whether the connections are acceptable or not. If the voltage difference is higher than a predetermined maximum amount, then the connection between the battery terminal 234 and the clamp 140 will likely be unacceptable.

If the connection is not acceptable, the battery tester charger 200 can alert or notify the operator. In some embodiments, the battery tester charger 200 may alert the operator as to which connection (positive or negative) is unacceptable or whether both are unacceptable. In some embodiments, the battery tester charger 200 may alert the operator that the connection(s) are acceptable. The operator may be alerted by a variety of ways, such as an indicator light, a message on a display screen, an audible signal, or other ways that are disclosed herein. Because the operator is warned that a connection is not acceptable, the operator may take corrective measures to improve the connection, such as cleaning or replacing the terminals 234, 236 or clamps 240, 238.

Referring to FIG. 1, in the preferred embodiment of the invention, a Sabre Battery Test procedure is used as a heavy load test to analyze the condition of the battery. The heavy load test is applied with a heavy load 144 that includes a solenoid switch 146. The solenoid switch 146 is operated by the FPGA 142 through the I/O control 134 via the CPLD 140. The solenoid switch 146 in the heavy load test ensures that a high load amperage test can be efficiently and safely

transmitted to the battery. One detraction in incorporating the solenoid switch **146** with the heavy load test is that it is not possible to make an exact determination of when the heavy load **144** is started or ended. This results from the mechanics of the solenoid switch **146** in that when the switch is turned off or on, it does not occur immediately. Therefore, there is a delay that fluctuates due to the mechanics of the solenoid switch **146** which makes exact testing and charging more difficult. One of ordinary skill in the art will recognize that the solenoid **146** can be replaced with electronic switching devices, such as transistors, in an alternate embodiment. However, cost considerations drive the design of the preferred embodiment and a mechanical solenoid switch **146** was selected.

The preferred embodiment analyzes the charge-state of a given type of battery, determines whether the battery is defective and, if not, charges the battery at its most optimum charge rate up to its maximum allowed charging volts. Furthermore, the preferred embodiment executes its analysis, determination, and charging in the safest and most optimal time possible.

In operation, the heavy load test is shown in the Sabre Test Timing Diagram **300** in FIG. **3**. The Sabre Battery Test requires a first applied load **302** to be placed on an open circuit **304**. A battery voltage reading ("LVA15") **306** can be taken at the end of the first applied load **302**, which is approximately fifteen seconds after the first load **302** is applied and released. A bounce back voltage measurement ("Rv") **308** is taken approximately twenty seconds after the first applied load **302** is turned off. A second applied load **310** is then placed on the open circuit **304** and maintained for approximately fifteen seconds. Another battery voltage reading ("LVB15") **312** is taken at the end of the second applied load **310**.

Heavy load tests are highly accurate for testing charged batteries. If the battery to be tested is partially charged, then the test accurately determines whether the battery is defective. A person skilled in the art will recognize that any heavy load test procedure that is suitable for testing the condition of the battery may be used. Additionally, load as used herein can also be a charge.

If the condition of the battery is such that the battery can be recharged, a preferred embodiment of the invention can calculate a set time to charge the battery. If LVB15 **312** is less than 4.0 V, the set time, i.e., maximum charge time, equals approximately forty-five minutes. If LVB15 **312** is equal to or greater than 4.0 V, the set charge time is calculated as follows:

$$\text{Set time} = (12.5 - V_{ss}) * 56.25 \text{ minutes}$$

Where,

V_{ss} = bounce back voltage ("Rv") if $11.7V \leq Rv \leq 12.5V$

$V_{ss} = 12.5V$ if $Rv > 12.5V$

$V_{ss} = 11.7V$ if $Rv < 11.7V$

By applying the heavy load test and monitoring the bounce back voltage, the charger **100** calculates the state of charge of the battery and the set time required to charge the battery while maintaining an optimum charge rate. The charger **100** controls the optimum charge rate by precisely controlling the charging voltage throughout the charging cycle.

If the battery condition can be charged, as determined by the heavy load test (e.g., Sabre Battery Test), further testing and charging will be performed. If the battery condition is determined to be faulty, then testing is terminated and the battery can be discarded. Therefore, the operator does not waste time and effort to charge the defective battery.

If the battery condition is determined to be functional, additional testing and charging are performed, as depicted in FIG. **4**. The first step in this testing is to determine whether the bounce back voltage is greater than 12.6 volts **400**. The bounce back voltage is a measure of the state of battery charge. If the bounce back voltage is determined to be greater than 12.6 volts, the battery tester/charger will perform a micro-load test **162**. If the bounce back voltage is equal to or less than 12.6 volts, the charger **100** is activated **402** to charge the battery for a set time **404**.

While the battery is being charged **402**, the current is monitored. If the charge is greater than five amps **406**, the charger **100** continues to charge for the set time. If the current is less than or equal to five amps **406**, the charger **100** continues to charge the battery for a minimum of at least five minutes **408**.

Once the set time or five minutes of charging **408** is reached, the charger **100** turns off **410**. A heavy load test is applied to the battery for at least ten seconds followed by the heavy load **144** being removed for at least twenty seconds **410**. The previous application and removal of the heavy load **144** is important to condition the battery by stabilizing the battery voltage. Another heavy load test **412** is then performed on the battery.

The charger **100** then determines from the heavy load test **412** if the battery is good **414**. If the battery is determined to be faulty or bad **416**, the testing is terminated and the battery is discarded. If the battery is determined to be functional **414**, or if the bounce back voltage is greater than 12.6 volts, the cold cranking amps ("CCA") are measured using a micro-load test **418**.

In the preferred embodiment, the micro-load test **418** is performed after the battery is determined to be functional by the heavy load test **412**. This microload test **418** is performed by applying a smaller load (approximately twenty to sixty amps) for a preset duration (approximately 250 milliseconds to one second) and measuring the CCA **420** after the micro-load **162** is removed. If the measured CCA is greater than 70% of the rated CCA **420** of the battery, then the battery is good and the charge is completed **424**, then the cycle ends at **426**. If the measured CCA is less than 70% of the rated CCA **420** of the battery, then it is bad battery **422** and will be discarded. It should be recognized that other micro-load tests could be substituted for the micro-load test **418** described above. For example, a dual micro-load test can also be used.

If the condition of the battery can not be determined from the heavy load test **412**, the charger **100** will charge the battery and retest it in accordance with the method depicted in FIG. **5**. For re-testing, the charger **100** is activated **500**. The charger **100** charges the battery for approximately one-minute **502**. The battery voltage is read after one-minute **504**. If the battery voltage **504** is less than one volt after one minute, then the battery is bad. The charger **100** is turned off and the battery will be discarded **506**.

If the voltage **504** is equal to or exceeds one volt after one minute of charging, the charger **100** will continue to charge for approximately nine minutes **508**. During the nine minutes of charging, the charging current is recorded or read at one-minute intervals to determine if the charging current exceeds three amps **510**. If the charging current is equal to or does not exceed three amps, the battery is determined to be bad **512** and the charger **100** is turned off and the battery is discarded.

If the charger's **100** current does exceed three amps, the charger will continue to charge for the set period of time as calculated above **514**. The charger **100** will apply the heavy

load **144** to the battery for a period of ten seconds to condition the battery and then removed the heavy load for a period of twenty seconds **516** for the battery voltage to stabilize. The heavy load test (e.g., Sabre Battery Test) is then performed **518**.

The charger **100** then determines whether the battery is good **520**. If the battery is determined to be bad **522**, it is discarded. If the battery is determined to be functional **520**, the CCA is then measured using the microload test **524**. The measured CCA is then compared to the rated CCA for the battery **526**. In the preferred embodiment of the invention, if the measured CCA is less than or equal to approximately seventy percent of the rated CCA for the battery **526**, then the battery is determined to be bad **528** and is discarded. If the measured CCA **526** is greater than approximately seventy percent of the CCA, then the battery is determined to be good **530** and the charge is completed **532**.

Referring to FIG. 1, the preferred embodiment contains an infrared temperature sensor **164**, which aids in monitoring both the charger **100** and the battery being charged. The infrared temperature sensor **164** ensures that both the battery and charger **100** are maintained at safe levels. In the preferred embodiment, the infrared sensor **164** is contained within a housing. The housing is placed over the charging battery for safety reasons especially in the instance that, while charging, the battery unexpectedly explodes. The housing aids in containing the surrounding areas from the contaminants of the exploded battery.

The infrared temperature sensor **164** is placed within the housing to monitor the temperature of a charging battery. While charging a battery, heat is discharged or dissipated from the battery. However, excessive heat is an indication that the battery is being charged at an excessive rate. In the preferred embodiment, the infrared temperature sensor **164** is linked to the ADC **136**, essentially an input to the ADC **136**, which relays the information to the CPLD **140**, which then relays it to the FPGA **142**. The FPGA **142**, with the help of the infrared temperature sensor **164**, can monitor the temperature of the battery and relay the information, including any problems to the operator. The infrared temperature sensor **164** is aimed at the battery to ensure that the temperature of the battery is being monitored throughout the charging process. For example, if the battery being charged contains a short, the battery will heat excessively in a short period of time. The feedback from the infrared temperature sensor **164** can be used to alert the operator of the problem so that the operator can take the appropriate action.

A gel battery can heat excessively during charging and therefore, the charging current is applied in relation to the heat detected. For this type of battery, a temperature is fixed after which point the charging current is reduced. By monitoring the temperature and adjusting the current in view thereof, the charging time is reduced. The temperature and charging current are proportionally related in specific types of batteries (e.g. gel). Thus, by monitoring the temperature and the charging current, the gel battery or other batteries can be charged efficiently, and explosions can be prevented during charging.

In another embodiment, the infrared temperature sensor **164** can be aimed at the charger **100** only or in combination with the battery. By monitoring the charger **100**, any excessive temperature generated by the charger can be relayed to the operator, thus appropriate actions can be taken to avoid overheating and damaging the charger.

One of ordinary skill in the art recognizes that the temperature sensor **164** can be located in a number of different locations, either located in the charger **100** or

linked to the charger **100**. The location of the infrared temperature sensor **164** is not limited to a housing. Additionally, temperature sensors are needed most when the battery is charging. Therefore, monitoring the temperature of the battery and/or the charger can help to prevent battery explosions.

In a preferred embodiment, a conventional processor is replaced by a dynamic FPGA **142**. The use of the FPGA **142** allows a designer to make changes to the charger **100** without having to replace the processor. Changes to a mounted conventional processor requires remounting and reconfiguration of the charger **100** design, which in turn requires more design hours and additional costs. With the use of the FPGA **142**, the designer is allowed to make changes on the fly without remounting or tireless reconfiguration of the initial design.

The FPGA **142** is configured and arranged to operate as a conventional processor. In the preferred embodiment, the FPGA **142** controls and processes a number of different functions of the charger **100**. One such function is the operation of the micro and heavy load tests **418**, **412**. These tests are downloaded and stored into a memory device **144**. It can also be stored in a RAM device **146**. Once stored in these memory devices **144**, **146**, the code is downloaded into the FPGA **142** and executed. Upon execution of the code, the FPGA **142** begins to operate various controls of the charger **100**, such as the solenoid switch **146** on the heavy load **144**, and the SCR **126** for current and voltage control. Additionally, data can be inputted into the FPGA **142** through the input device **148**, such as a keypad. The FPGA **142** can transmit to and receive information from an output display **150**, a serial port **154**, such as a printer port, a second serial port **152**, such as an infrared bar code reader, a module port **156** that can accept various communication modules, or any other device that can communicate with the FPGA.

Upon start-up or boot-up of the charger **100**, an image of a soft-core microprocessor is loaded from the memory (i.e. flash **144**, RAM **146**, etc.) into the FPGA **142**. Therefore, there is an image of the FPGA **142** resides in the memory. Additionally, upon start-up, the CPLD **140** takes control of the data and address bus and clocks the FPGA **142** image from memory into the FPGA **142**. As stated previously, this allows for redesign of the processor and the board without the need for remounting a processor. All that is necessary for a design change is to upload a new FPGA image into the memory device. Additionally, any new tests or operating parameters that is required by the operator can be easily upload into the FPGA **142** and executed. The preferred embodiment uses flash memory **144** to accomplish this function.

The output display **150** can be an integrated display or a remote display that relays information, such as data gathered from the charging and testing of the battery, and menu information. Additionally, the display **150** can notify the operator of any problems that have been detected. The serial port **154** in the preferred embodiment are standard RS-232 serial ports for connecting a device, such as a printer. One of ordinary skill in the art will recognize that the RS-232 can be replaced with an RS-432, an infrared serial port or a wireless radio frequency port, such as BLUETOOTH™, or any other similar device.

In some embodiments of the current invention, a bar code port **152** is provided. The bar code port **152** may serve to operably connect a bar code reader (not shown) to the FPGA **142** or a microprocessor. In some embodiments, the bar code port **152** may be a conventional component, such as an

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RS-232. The bar code reader may be, for example, a conventional optical bar code reader, such as a gun or a wand type reader.

The operator swipes or aims the bar code reader on a bar code that is associated with the particular battery to be charged or tested and reads the bar code. The bar code itself may be affixed to the battery at the time of manufacture, purchase, or service. The bar code may contain information, or point to information stored in a database. The database may be located within the FPGA **142**, the storage media **168** (below) or located remotely and accessed electronically. Examples of remotely located databases include data based accessible by the Internet, Ethernet, or other remote memory storage facility.

The bar code may provide a variety of information regarding the battery. For example, the bar code may provide information regarding the battery type (e.g. gel, flooded lead acid, deep cycle), the battery rating (cold cranking amps), maintenance information, serial number, lot number, warranty information, and a manufacture date code. This data can be used to select parameters for the test or charge cycle. The data provided by the bar code is not limited to the examples given.

In some embodiments, the printer port **154** may print bar code labels that may be attached or otherwise associated with the battery and provide updated information. The updated information may include, among other things, service dates, service procedures, and warranty information (e.g. time left on warranty, who was the original purchaser, what types of service are and are not warranted, etc.) The printed label may then be read by the bar code reader in subsequent tests or charge cycles.

The output display **150** and an input device **148** are illustrated in a preferred embodiment in FIG. 6. The display **150** and input device **148** can be located preferably on a common face of a cabinet of the charger **100**, although they alternatively can be located remote from each other and/or remote from the cabinet of the charger, if desired. The display **150** can include one or more LED's indicating states of the charger **100** or the battery during charging or testing. For example, LED **652** indicates that power is applied to the unit, LED **653** indicates a charge is being applied to the battery, LED **654** indicates a fault in the battery, and LED **655** indicates a good battery is detected. A segmented or dot matrix type, alphanumeric LCD display **656** may also be provided as part of the output display **150**. For example, as shown in FIG. 6, the display **656** can be a 4 by 20 backlit LCD display, having four rows each having twenty character columns. This permits display of a wide range of information relating to e.g., charging status, time, amount, etc, as well as display and selection from a menu of control functions. Thus, the display **150** can include either the alphanumeric display **656**, the LED's **652** to **655** or both. The two types of displays can be on a single panel or separate ones.

Control functions may be inputted via at least one, preferably two and more preferably three or more functional buttons, such as up down buttons **658**, and a menu select button **660**. A ten key alphanumeric keypad **662** may also or alternatively be provided for input of numeric data, alphabetic data, and/or command selection. Each key can provide for entry of a number, one or more letters, and/or a function. Thus, the input device **151** can include the menu button **660**, the up down buttons **658**, the alphanumeric keypad **662**, or a combination thereof. These arrangements can be on a single panel or separate ones.

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For example, the key labeled GO may generally be used in the affirmative. It usually means continue on. It is also used to initiate menu prompts leading to the test/charge sequence. The key labeled CLEAR can generally be used in the negative. It is generally used to clear a value that is to be entered. It may also be used to break out of a process or back out of a menu sequence. The key labeled MENU can be used to initiate the function menu. It is also used to back out of a menu sequence. The ARROW KEYS can be used to navigate within the menus and display screens. If an arrow is displayed on the right of the display, the corresponding arrow key can be used to "move" the view to another part of the menu or screen. The arrow keys may also be used to increment or decrement a displayed value. The NUMBER KEYS can be used to communicate with the application in a number of ways. They can be used to indicate the selection on a menu. They can also be used to provide numerical and/or alphabetical input to an application parameter.

The screen may include the ability to scroll through a set of menu items, such as for example, the following:

- a) Top level menu, (GO or MENU)
- b) Function Menu:
 - 1-Test Results
 - 1-View results
 - 1-Print results
 - 2-Print engineering data
 - 2-Print results
 - 2-Setup
 - 1-Set Clock
 - 2-Set Language
 - 3-Set Printer Port
 - 4-Ethernet Setup
 - 5-Save setup
 - 3-Self Test
 - 1-LCD Test
 - 2-keypad Test
 - 3-LED Test
 - 4-Audio Test
 - 5-Watchdog Test
 - 6-Load Cycle Test
 - 7-RAM test
 - 8-Checksum application
 - 9-Test Barcode Reader
 - 4-Update S/W
 - 5-Utility menu
 - 1-print codes
 - 2-upload data
 - 6-Calibrate
 - 1-Set DAC0
 - 2-Set DAC1
 - 3-Set Amps Offset
 - 4-Set Amps Gain
 - 5-Set Volts Offset
 - 6-Set Volts Gain
 - 7-TemperatureOffset
 - 8-Manual Controls
 - 1-Test SCR
 - 2-Enable SCR load
 - 3-Enable Low Volts Charging
 - 4-Auto Charge Mode
 - 5-Heavy Load Test
 - 6-Micro Load test
 - 7-Manual Charge Mode
 - 8-Monitor Volts
 - 9-Save Calibrations

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This menu is by way of example only. Other features, commands, displays or inputs, for example may also be provided.

Referring to FIG. 1 an additional smaller transformer **158** provides current and voltage to the I/O control **134** and a cooling fan **160**. The smaller transformer **158** provides a step down of both the voltage and current to a level that enables the I/O control **134** and a cooling fan **160** to operate. The cooling fan **160** helps to control the operating temperature of the charger **100**.

The peripheral module port **156** can be constructed and arranged to receive an information relay device, such as an Ethernet wired module **166** and/or an Ethernet wireless module **164**. The Ethernet modules **164**, **166** communicate at data rates of 10 Mbps (10Base-T Ethernet), 100 Mbps (Fast Ethernet), 1000 Mbps (Gigabit Ethernet), and other data rates. The Ethernet modules **164**, **166** can relay information between the charger **100** and another device connected to the modules via a wire or wirelessly. The information relayed can include data from the result of the charging/testing of the battery, data of the battery's warranty information, data of the battery type (deep cycle, gel, etc.), data of battery make and model, data from previous charging/testing of the battery, firmware update, data from diagnostic or operating parameters of the charger **100**, maintenance data of the charger **100**, and any other data required by the operator.

The peripheral module port **156** is in communication with the FPGA **142**. Information can be exchanged between the peripheral module port **156**, the Ethernet modules **164**, **166**, and the FPGA **142**. The Ethernet modules **164**, **166** can relay the information to and from a remote device, such as a network server, a printer, a personal computer, a workstation, a file server, a print server, other communication devices, such as a fax machine, a cellular/digital phone, a pager, a personal digital assistant, an email receiver, and a display. Through the use of the Ethernet modules **164**, **166** any information, such as the information of the battery tested by the charger **100**, can be relayed to a printer server and printed. Thus, the charger **100** is not dependent on a stand-alone printer that may be down, and can print to any networked printer, thereby saving time and money to the operator.

With the Ethernet module **164**, **166**, information can also be stored remotely, such as on a workstation, a file server or other data storage device. For example, after the charger **100** concludes the charging/testing of the battery, the information from the test/charge can be relayed and stored on a networked personal computer. With the information stored on the networked personal computer, the information from any previous charge/test can be compared with the latest information, a report can be generated and forwarded to the appropriate personnel.

If the chargers **100** (same or similar model) that are used by the operator are "networked" together, the chargers' firmware can be updated simultaneously. Conventionally, to update firmware, a laptop is hooked up to the charger **100** and the new firmware is uploaded. Once the upload is completed, the operator then must go to the next charger **100** and repeat the process until all of the chargers **100** are updated with the new firmware. By being able to upload new firmware onto networked chargers **100**, the update process will be less time consuming, and thus cost-effective for the operator. By having the chargers **100** networked via the Ethernet modules **164**, **166**, information from all the chargers **100** can be relayed and displayed to the operator. Because the chargers **100** can be networked, the operator

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does not have check each individual charger **100** to see if the charging and testing is completed and saves valuable time and money. Additionally, by being networked, the chargers **100** can be instructed to run diagnostics and other functions remotely without having to individually program each charger **100**.

In another embodiment, a notification system is provided to notify the operator when there is a problem with the charger **100** or the battery or when the charging/testing is completed. Typically, the operator has to physically check the status of the charger **100** and often would have to return many times to see if the charging/testing is completed. With the charger **100** having an Ethernet connection modules **164**, **166**, the status information can be relayed to a remote location, such as the network server or the personal computer, which can be programmed to notify the operator of any problems or the completion of the charging/testing. Because the operator can be notified of any problems, the operator can take appropriate measures, such as terminating the charging of the battery, because charger **100** or the battery is overheating. By being notified of any problems, the operator can save money due to a decrease in electricity usage and decrease the possibility of an explosion due to overcharging the battery. Notification of the operator can be done with a personal computer that can notify the operator via another display, by pager, by fax, by email, by phone, by computer or by any means that will relay the requested information to the operator.

In another embodiment of the invention, the peripheral module port **156** can be constructed and arranged to accept a removable data storage media **168** ("storage media"). Information can be exchanged between the peripheral module port **156**, the storage media **168**, and the FPGA **142**. The storage media **168** can be permanently fixed to the charger **100** to provide additional memory or can be removable, as required by the operator. The storage media **168** can transfer information to and from the charger **100**. The information can include data from the result of the charging/testing of the battery, the battery's warranty information, the battery type (deep cycle, gel, etc.), the battery's make and model, data from previous charging/testing of the battery, firmware update, data from diagnostic or operating parameters of the charger **100**, maintenance data of the charger **100**, and any other data required by the operator.

The storage media **168** can include, but not limited to floppy disc (including ZIP); tape drive cartridge (such as DAT); optical media (such as CD-ROM, DVD-ROM, etc.); flash memory (such as smart media, compact flash, PC card memory, memory sticks, flash SIMMs and DIMMs, etc.); magnetic based media, magneto optical; USB drives; or any other storage media that an operator can store or retrieve information from it. A person skilled in the art will recognize that any storage media can be used.

One use of the storage media **168** is to update firmware, wherein the storage media can be programmed with the firmware update and loaded into the charger **100**. By using the user interface **148**, the operator can select the "update firmware" option from a menu that was previously provided to the charger **100**. The charger **100** is able to retrieve the new firmware and update the charger **100**. In another example, the operator can use the storage media **168** to store information regarding the battery that was charged/tested. The information can be downloaded into the storage media **168**, such as a compact flash card, and can be sent to the appropriate person. Additionally, the storage media **168** can contain information from the charging/testing result of a battery at another location and can be uploaded into the

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charger 100 and displayed to the operator. Alternatively, the information can be relayed via the Ethernet module to be viewed, stored, or printed at a remote location. The storage media 168 can also provide an image of a soft-core micro-processor to the FPGA 142 during start-up.

The charger 100 can have more than one peripheral module port 156 so that a communication module, a storage media module, and an many other modules as needed can be onboard the charger. The peripheral module port 156 provides flexibility to the charger 100 and provides a port so that any new device can be added to the charger as needed by the operator.

The many features and advantages of the invention are apparent from the detailed specification, and thus, it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirits and scope of the invention. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

What is claimed is:

1. An apparatus for charging a battery comprising:
 - a power transformer;
 - a rectifier located at an output of the transformer;
 - a switch positioned at an output of the rectifier;
 - an input that is configured to allow a selection of a desired voltage and current, wherein the selection of the desired voltage and current results in a set-point;
 - a microprocessor linked to the switch, the microprocessor configured to determine the operability of the switch by comparing the set-point with an output value from the rectifier and operating the switch accordingly, wherein the set-point is placed at location on the sine wave and based upon the voltage selection.
2. The apparatus as in claim 1, wherein the battery is a lead-acid battery.
3. The apparatus as in claim 1, wherein the switch is a thyristor.
4. The apparatus as in claim 1, wherein the microprocessor is a field programmable gate array (FPGA).
5. The apparatus as in claim 4, wherein a set-point is provided to the FPGA.
6. The apparatus as in claim 5, wherein the FPGA calculates what voltage to pass through the switch in response to the set-point.
7. The apparatus as in claim 6, wherein the set-point determines a position on a rectifier output, which triggers the switch to pass a range of the voltage to the battery.
8. The apparatus as in claim 4, wherein the microprocessor is a computer programmable logic (CPLD).
9. The apparatus as in claim 5, wherein the set-point is based upon a desired battery voltage charge.
10. The apparatus as in claim 5, wherein the set point is based upon a desired battery current charge.
11. A method for charging a battery comprising:
 - receiving a voltage selection for supplying voltage to a battery;
 - creating a set-point based upon the voltage selection, wherein the set-point is arrived at by a microprocessor;
 - comparing the setpoint with an output value from a rectifier;

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regulating a switch to permit voltage to pass through to the battery based upon the comparison:

receiving the voltage from a power transformer to apply to the battery, wherein the voltage is a rectifier sine wave;

charging the battery with the voltage that is permitted to pass through to the battery, wherein the set-point, is used to determine a location on the rectified sine wave based upon the voltage selection.

12. The method as in claim 11, further comprising preventing the voltage from reaching the battery when the output value from the rectifier is greater then the set-point.

13. The method as in claim 12, wherein all the voltage from the set-point forward is allowed to pass to the battery.

14. An apparatus for charging a battery comprising:

- means for receiving a voltage selection for supplying voltage to a battery;

means for determining a set-point based upon the voltage selection;

means for comparing the setpoint with an output value from a rectifier;

means for regulating a switch to permit voltage to pass through to the battery based upon the comparison;

means for charging the battery with the voltage that is permitted to pass through to the battery;

means for receiving the voltage to apply to the battery from a means for rectifying, the voltage outputted from the means for rectifying is an alternating current supply in the form of a sine wave,

wherein the set-point is placed at location on the sine wave and based upon the voltage selection.

15. The apparatus as in claim 14, further comprising means for preventing the voltage from reacting the battery when the value from the rectifier is greater than the set point value.

16. The apparatus as in claim 14, wherein all the voltage from the set-point forward is allowed to pass to the battery.

17. An apparatus for charging a battery, comprising:

a battery charger configured to charge a battery;

an input device that is configured to receive a desired voltage in order to charge the battery;

a processor device linked to the battery charger, the processing device is configured to determine a se-point based upon the desired voltage; and

a regulator linked to the battery charger and processor, wherein the processor regulates a voltage from the battery charger to the battery based upon the set point, wherein the set-point is placed at location on a sine wave and based upon the desired voltage.

18. The apparatus as in claim 17, wherein the processor device is a field programmable gate array (FPGA).

19. The apparatus as in claim 17, wherein the processor device is a microprocessor.

20. The apparatus as in claim 17, wherein the voltage selection is a desired battery voltage.

21. The apparatus as in claim 17, wherein the regulator permits only certain voltages to pass to the battery.

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 7,148,657 B2
APPLICATION NO. : 10/235794
DATED : December 12, 2006
INVENTOR(S) : Kurt Raichle et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 15

Line 55, please replace "set point" with --set-point--;

Column 16

Line 44, please replace "se-point" with --set-point--;

Line 48, please replace "set point" with --set-point--.

Signed and Sealed this

Sixth Day of February, 2007

A handwritten signature in black ink on a dotted background. The signature reads "Jon W. Dudas" in a cursive style.

JON W. DUDAS

Director of the United States Patent and Trademark Office